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CHAPTER 5

CHRONIC BRONCHITIS: INTERACTION OF SMOKING AND OCCUPATION

CONTENTS

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Introduction

Occupational bronchitis is defined as the occurrence of bronchitis caused by worksite chemical or physical agents, whether encountered as gases, fumes, vapors, or dusts. Having derived from a crowded field of overlapping and confusing terms, the term "occupational bronchitis" has inherited a certain inexactitude and has been applied with ambiguity. To complicate the issues further, some industrial substances that cause bronchitis also frequently cause other lung diseases, especially the pneumoconioses and asthma, the symptoms of which may mimic those of occupational bronchitis. Studies of these occupational lung diseases have not always differentiated clearly between the development of bronchitis and the development of other lung disorders. Hence, this review begins by briefly applying the customary distinctions in terminology to the area of occupationally derived bronchitis.

Whether caused by cigarette smoking, industrial agents, or otherwise, "chronic simple bronchitis" denotes the presence of persistent cough with phlegm production not attributable to a specific pulmonary disease such as bronchiectasis or tuberculosis (Ciba 1959; American Thoracic Society 1962). The operational definition of this form of bronchitis provided by consensus groups of American and British investigators 20 years ago has been widely used in industrial and nonindustrial studies: cough and sputum production on most days for at least 3 months annually for 2 consecutive years (Ciba 1959). Fletcher and coworkers (1976) subsequently demonstrated that this hypersecretory disorder among cigarette smokers can occur independent of airway obstruction and does not of itself lead to an obstructive disorder. Brinkman and colleagues (1972) confirmed these findings in an occupational setting in a more abbreviated study. Mucus production causes morbidity in that it may lead to increased pulmonary infections, but it does not cause significant dyspnea or potentially disabling obstructive disease.

"Chronic obstructive bronchitis" often included in the generic term "chronic obstructive pulmonary disease" (COPD), is defined by the presence of airflow obstruction as measured in most occupational studies by the reduction in the ratio of forced expiratory volume in 1 second to forced vital capacity (FEV_1/FVC). More recently, flow rates at low lung volumes obtained from the same forced expiratory maneuver have been used to detect dysfunction of the small airways. In contrast to the mere production of cough and phlegm, the presence of obstruction may have important impact on morbidity and mortality (Fletcher et al. 1976). This subject is reviewed more fully elsewhere in this Report.

The term "occupational bronchitis" has been used more often to refer to simple bronchitis than to the airflow obstructive disorder

because of the widespread notion that many airborne occupational contaminants produce chronic cough and phlegm, but relatively few agents have been found to lead to measurable airflow obstruction or to clinically significant COPD (Parkes 1982; Casey 1983; Kilburn 1980; Morgan and Seaton 1984).

Two related criteria have commonly been used to demonstrate the existence of occupational bronchitis in the presence of a specific exposure or in a specific workplace. First, occupational bronchitis is favored if excessive rates of respiratory symptoms are found in workers who have never smoked. The obvious advantage of such a criterion is the elimination of cigarette smoking, which is a major confounding variable in bronchitis. Unfortunately, this approach could fail to incriminate an occupational agent that produces no respiratory effects by itself but causes higher rates of bronchitis among workers who smoke than are attributable to cigarette smoking alone. Second, the entire exposed population—smokers, former smokers, and nonsmokers—may experience higher rates of chronic cough and phlegm production than a similarly constituted unexposed control population. If the population of exposed nonsmokers is small, however, only the interactive effects of smoking and the occupational agent of interest may be evaluated.

This chapter describes the impact of smoking and occupational exposures on the prevalence of simple bronchitis. Examining the interaction between smoking and hazardous substances, however, requires documenting the ability of industrial agents alone to produce chronic respiratory disease. The additional or multiplicative effects of cigarette smoking can then be described. Emphasis is placed on evaluating the nature and quality of data rather than on compiling a complete list of agents putatively associated with bronchitis.

Coal

The role of coal dust in the development of chronic simple bronchitis has been examined (Morgan and Seaton 1984; Parkes 1982), and respiratory disease in coal miners is discussed more fully in a separate chapter of this Report. The specific issue of bronchitis and occupational exposure to coal is reviewed briefly in this section.

Evidence supports an independent causal relationship for both cigarette smoking and coal dust in chronic cough and phlegm production (Higgins et al. 1959; Saric and Palaic 1971; Higgins 1972; Lowe and Khosla 1972; Kibelstis et al. 1973). In a series of community-based studies in England and in the United States during the 1950s and 1960s, Higgins and colleagues (Higgins et al. 1959; Higgins 1972) found an increased prevalence of chronic simple

bronchitis in miners and ex-miners, ranging from 1.2 to 6.4 times the rates in nonminer controls.

Lowe and Khosla (1972) studied chronic bronchitis among more than 12,000 Welsh steelworkers, about one-fourth of whom were former coal miners. In the absence of cigarette smoking, previous exposure to coal dust increased the rate of chronic cough and phlegm production from 5.7 percent in nonsmoking nonminers to 13.6 percent in nonsmoking ex-miners. Cigarette smoking was somewhat more important than previous exposure to coal in producing chronic simple bronchitis; 16.6 percent of the nonminers who smoked and 25.5 percent of the ex-miners who smoked had chronic bronchitis. Differences in age among the various subgroups did not account for the varying prevalence of symptoms, which appeared to be additive.

Saric and Palaic (1971) compared 904 Yugoslav coal miners with 342 control workers of similar socioeconomic status without occupational exposure to dusts, and found that cigarette smoking and coal dust exposure were multiplicative in the production of chronic simple bronchitis. Of the miners who smoked, 32 percent reported chronic cough and phlegm production, compared with 10 percent of the controls who smoked, 8 percent of the nonsmoking miners, and 2 percent of the nonsmoking controls. However, the rates of chronic simple bronchitis for each exposure subgroup, except the workers who smoked, were below other published rates.

Increasing coal dust exposure increased the prevalence of chronic simple bronchitis in both smokers and nonsmokers in the studies by Kibelstis and colleagues (1973) and Rae and colleagues (1971). Neither study included groups not exposed to coal dust. Both studies reported a larger effect of cigarette smoking than of coal dust exposure in causing chronic simple bronchitis, but did demonstrate a substantial coal dust exposure effect. One-third to one-half of the nonsmoking American coal miners over the age of 50 reported chronic cough and phlegm production (Kibelstis et al. 1973). Somewhat lower proportions (20 to 40 percent) of the nonsmoking British coal miners with the highest levels of dust exposure suffered symptoms of chronic cough and phlegm production (Rae et al. 1971).

In summary, coal dust exposure causes chronic simple bronchitis independent of cigarette smoking. Although the effects are additive, the effect of smoking is somewhat greater than the effect of coal dust exposure in producing symptoms of chronic bronchitis.

Silica

Early studies showed no relationship between silica exposure and chronic cough and phlegm production. In 1959, Higgins and colleagues (1959) found no increase in chronic simple bronchitis in British foundry workers and former foundry workers, regardless of

duration of employment, compared with community controls without dust exposure. In a cross-sectional study, Brinkman and Coates (1962) found no difference in cough and phlegm production in long-term American foundry workers with normal chest roentgenograms and control workers with no dust exposures. More recently, Glover and colleagues (1980) examined 725 Welsh slate workers and former workers and noted no relation between duration of exposure to slate and presence of chronic simple bronchitis independent of pneumoconiosis.

On the other hand, studies of South African gold miners showed an association between silica and simple bronchitis among smoking miners. White miners were compared with age-matched white nonminers in an area where gold mines had a 50 to 70 percent free silica content (Sluis-Cremer et al. 1967). Nonsmoking miners reported an 8.2 percent rate of chronic simple bronchitis, which did not differ from the 6.7 percent rate found among nonsmoking nonminers. However, 50.5 percent of the miners who smoked had chronic cough and phlegm production, almost twice the 28.0 percent found among the nonminers who smoked. Hence, silica dust alone appeared not to cause symptoms of simple bronchitis, but magnified the effects of smoking.

Wiles and Faure (1977) also studied white South African gold miners and found that they had an increased prevalence of bronchitic symptoms in the absence of cigarette smoking and that there was an additive effect among the workers who did smoke cigarettes. Among the nonsmokers with the lowest dust exposure, no workers had chronic cough with phlegm, but 15 to 20 percent of workers with the highest dust exposures had these symptoms. Twenty-five percent of smokers in the low dust category reported bronchitic symptoms. Among the miners who smoked, 50.5 percent suffered from chronic cough and phlegm production, demonstrating a simple additive effect.

A cross-sectional study of 931 Swedish long-term foundry workers with varying exposures to silica was published in 1976 (Karava et al. 1976). Less than 4 percent of the study population had evidence of silicosis on chest x ray. Two percent of the nonsmokers exposed to lesser amounts of dust reported simple chronic bronchitis compared with 9 percent of the nonsmokers with high dust exposure, but the difference was not significant ($p > 0.10$). However, 16 percent of the smokers exposed to slight or moderate levels of dust had chronic cough and phlegm production, significantly less than the 30 percent of smokers with high dust exposure ($p < 0.01$). Foundry dust may have potentiated the effect of cigarette smoking.

In summary, silica exposure appears to interact with cigarette smoking to increase the prevalence of chronic bronchitis, at least in white South African gold miners.

Cement

A cross-sectional survey of 847 cement workers and 460 controls not exposed to occupational hazards found that 19.0 percent of the cement workers had chronic simple bronchitis, compared with 9.62 percent of the control group, using the Medical Research Council (MRC) (*British Medical Journal* 1966) criteria for bronchitis (Kalacic 1973a, b, 1974). However, the study group had more current smokers and was somewhat older than the control group (Kalacic 1973a). The nonsmoking cement workers had significantly more chronic simple bronchitis than the nonsmoking control subjects: 11.7 and 2.2 percent, respectively ($p < .001$). The cement workers who smoked cigarettes reported a 21.2 percent rate of chronic simple bronchitis, twice the rate of the nonsmoking cement workers.

An investigation of the relationship between chronic bronchitis and occupation among 14,154 persons in numerous occupations, including 344 cement workers (Deutsche Forschungsgemeinschaft 1978), revealed a positive association between the symptoms of chronic bronchitis and exposure to cement dust only in heavy smokers and younger nonsmokers.

In summary, cement dust exposure may cause chronic simple bronchitis independent of cigarette smoking. The interaction between the two exposures is likely to be additive.

Grain

Although for several decades cereal grain dust has been known to affect human lungs (Williams et al. 1964; Kleinfeld et al. 1968), the nature of grain-related chronic lung disease and its relationship to cigarette smoking has been elucidated only in recent years. Complicating factors have included the variety and overlap of the lung diseases associated with grain dust (asthma, allergic alveolitis, grain fever, and chronic obstructive lung disease) and the multitude of potentially toxic materials found in grain dust (various cereal grains, fungi, mites, insects, and pesticides) (Dosman et al. 1979).

Dosman and colleagues (1980) compared 90 lifetime nonsmoking grain workers with 90 lifetime nonsmoking control subjects selected randomly from a hospital service plan in the same Canadian Province. Study subjects and controls were individually matched for age, resulting in a mean age of 30.8 years for both groups. Using modified MRC criteria for the diagnosis of chronic bronchitis, the investigators found that 23.1 percent of the grain workers had cough and phlegm production compared with 3.1 percent of the control subjects, an eightfold difference. Among the grain workers, the rate of chronic bronchitis rose with duration of employment from 14.3 percent of the workers with less than 5 years of employment to 35.7

percent of the workers with over 20 years' tenure, an increment not seen with increasing age among the control workers.

Other studies of smaller groups of nonsmoking grain handlers have been less impressive. Broder and colleagues (1979) compared two groups of Canadian grain workers (26 and 39 workers, respectively) with 40 civic workers: all three groups had never smoked. Mean duration of employment was at least 9 years. Symptoms of chronic simple bronchitis occurred in 12 and 8 percent of the grain handlers, respectively, and in 3 percent in the control workers. Do Pico and colleagues (1977) reported that 30 percent of 57 grain workers who did not smoke met the MRC criteria for chronic bronchitis. No control group was studied.

Comparison of 610 grain elevator workers in British Columbia with 136 civic workers and 187 noncedar sawmill workers (Chan-Yeung et al. 1980) showed no significant differences in prevalence of cough or phlegm production among the nonsmokers. However, the two control groups had higher rates of symptoms than the control groups from other studies.

Dosman, Cotton, and their colleagues (Cotton et al. 1983; Dosman et al. 1984) updated their 1980 study with reports of larger cross-sectional studies in 1983 and 1984. Rates of chronic bronchitis in 195 lifetime nonsmoking grain workers (approximately 15 percent) versus 195 age-matched lifetime nonsmoking control workers (about 3 percent) were similar to those found in the previous study (Dosman et al. 1980).

The interaction between smoking and grain dust exposure has received some attention. Dosman and others presented data relevant to chronic simple bronchitis in an editorial (Dosman et al. 1979). Rates of chronic cough with phlegm production in the four exposure groups are shown in Table 1. Smoking had a somewhat greater effect than grain dust on the prevalence of symptoms of chronic bronchitis. The combination of exposures reflected an additive effect of the individual exposures. A later study by Dosman's group (Cotton et al. 1983) yielded very similar results, with an additive interaction between smoking and grain exposure, albeit each group experienced lower rates of chronic bronchitis than in the 1979 study.

Other studies are less definitive about the nature of the interaction between cigarette smoking and grain exposure on the prevalence of chronic simple bronchitis, either because they lacked a nonexposed control group (Do Pico et al. 1977) or because smoking or grain exposure did not show significant independent effects on rates of chronic bronchitis (Chan-Yeung et al. 1980; Broder et al. 1979). The results of these studies suggest at most an additive effect between smoking and grain exposure.

TABLE 1.—Prevalence of chronic bronchitis in grain-exposed workers and controls

Exposure group	Percent with chronic bronchitis	Morbidity ratio
Nonsmoking controls	3.5	1
Nonsmoking grain-exposed workers	16.5	4.7
Smoking controls	25.0	7.1
Smoking grain-exposed workers	36.5	10.4

SOURCE: Modified from Dosman et al. (1979).

Polyvinyl Chloride and Vinyl Chloride

Polyvinyl chloride (PVC) and related compounds, including vinyl chloride monomer and products of decomposition, have been implicated in asthma (Bardana et al. 1980), lung cancer (Wagoner 1983), and pulmonary fibrosis (Mastrangelo et al. 1979; Cordasco et al. 1980; Lilis 1980).

In a series of studies in the mid-1970s, Miller and Lilis and colleagues (Miller et al. 1975; Lilis et al. 1976; Miller 1975, 1980) evaluated approximately 900 active or retired polyvinyl chloride production workers exposed to a variety of levels of PVC dust and vinyl chloride gas in three separate facilities. Rates of chronic cough and phlegm production were 20.4 and 16.0 percent, respectively, among the workers in two of the plants, most of whom were smokers. Nonsmokers were not analyzed separately for symptoms, and no control group was studied. The authors (Miller et al. 1975) stated that the prevalence of chronic simple bronchitis in PVC production workers was similar to that found in studies of industrial and nonindustrial populations.

Gamble and colleagues (1976) studied 327 either active or retired PVC and vinyl chloride workers at one plant and found a smoking-adjusted prevalence of chronic simple bronchitis of 2.5 percent.

Soutar and colleagues (1980) performed a cross-sectional study of 818 Scottish PVC manufacturing workers, most of whom were actively working. Airborne dust levels were used to calculate a dust index. The authors found no relation between dust exposure index and prevalence of chronic cough and phlegm production.

In conclusion, the studies of the effects of PVC dust and vinyl chloride gas have not shown an association with symptoms of chronic simple bronchitis.

Welding

Welding entails a variety of methods, materials, and potentially hazardous exposures (Challen 1974; Parkes 1982). Welders may be

exposed to irritants such as nitrogen dioxide, ozone, and phosgene, to metal fumes such as cadmium, zinc, and iron, and to dusts including free silica and asbestos (Parkes 1982). Hence, the task of elucidating welders' respiratory disorders independent of cigarette smoking, if any, and tying these disorders to specific exposures has been difficult (Parkes 1982; Morgan and Seaton 1984).

In an early study, Hunnicutt and colleagues (1964) compared 100 electric arc welders with over 10 years of welding experience in a shipbuilding plant with 100 other workers in the same plant. Smoking and welding had equivalent effects on rates of cough and phlegm production and the effects were additive.

Fogh and colleagues (1969) examined 156 welders, mostly electric arc welders, and 152 control workers from shipyards and engine- and tank-producing facilities. The groups had similar smoking habits and similar rates of chronic simple bronchitis.

Peters and colleagues (1973) compared the pulmonary status of 61 welders, 63 pipefitters, and 61 pipecoverers from the same shipyard. Age (mean, 50 years) and smoking habits of the three groups were similar. No welders had radiographic evidence of siderosis. No differences between groups in rates of chronic cough were observed.

In a Roumanian study (Barhad et al. 1975), 173 shipyard welders were compared with 100 shipyard workers of other trades, but with similar age and smoking habits, and no significant difference in rates of chronic simple bronchitis were observed.

Antti-Poika and colleagues (1977) investigated symptoms in 157 electric arc welders without siderosis on chest x ray and 108 control workers from engineering shops, matched for age, smoking, and social class. The study workers and the control workers were relatively young, with mean ages of 36.1 and 36.8 years, respectively. Under the modified MRC criteria, chronic simple bronchitis was reported in 24 percent of the welders versus 14 percent of the controls ($p < .01$). Nonsmokers and smokers were not analyzed separately.

Oxhoj and colleagues (1979) studied 119 electric arc welders and 90 clerks from a shipyard. The nonsmoking welders and the ex-smoking welders had higher rates of chronic cough and expectoration than the comparable controls (31 and 11 percent, respectively). The welders who smoked experienced the highest rates of symptoms (77 percent) compared with the controls who smoked (43 percent). Hence, smoking and welding had an approximately equivalent ability to produce chronic simple bronchitis and the effects were additive.

In conclusion, chronic simple bronchitis has been related to welding apart from smoking habits in some of the studies reviewed. Smoking and welding have produced additive rates of respiratory symptoms in those studies that have shown an effect.

Sulfur Dioxide

Archer and Gillam (1978) compared 953 copper smelter workers and 252 control workers drawn from a nearby copper mine maintenance shop. With the smokers and nonsmokers combined, symptoms of chronic simple bronchitis were noted in 15.8 percent of the smelter workers compared with 9.5 percent of the control workers ($p < .05$); the smelter workers smoked slightly more than the control workers. Smoking was more important than the sulfur dioxide exposure in causing symptoms of cough and phlegm production, and the effects of the two factors appeared to be additive.

Other Exposures

Rubber curing workers had a 25.8 percent rate of chronic cough and phlegm production versus 14.3 percent for the controls ($p < .01$) (Fine and Peters 1976). The difference between nonsmokers was not significant (5.9 and 12.0 percent in controls and workers, respectively). However, the difference between smokers was significant (17.4 and 29.2 percent in controls and curing workers, respectively; $p = .03$).

In a comparison of 312 coke ovenmen with 464 other coke workers of similar ages (Walker et al. 1971), chronic simple bronchitis was reported in 32 percent of the smoking ovenmen versus 23 percent of the other coke workers who smoked ($p < .02$). Among the nonsmokers, 9 percent of the ovenmen noted these symptoms compared with 6 percent of the other coke workers, an insignificant difference. Hence, coke oven exposure potentiated the bronchitic effect of smoking.

Summary and Conclusions

1. Chronic simple bronchitis has been associated with occupational exposures in both nonsmoking exposed workers and populations of exposed smokers in excess of rates predicted from the smoking habit alone. Among these exposures are coal, grain, silica, the welding environment, and to a lesser extent, sulfur dioxide and cement.
2. The evidence indicates that the effects of smoking and those occupational agents that cause bronchitis are frequently additive in producing symptoms of chronic cough and expectoration. Smoking has commonly been demonstrated to be the more important factor in producing these symptoms.

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CHAPTER 6

ASBESTOS-EXPOSED WORKERS

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Introduction

Cigarette smoke and asbestos are agents with well-documented risks associated with exposure. Large numbers of individuals have had exposure to either or both of these agents sufficient to generate significant excess death and disability. The focus of this review is the effects of combined exposure to asbestos and cigarette smoke. The literature that establishes the causal nature of the risks associated with each of these exposures and the nature and extent of the disease that can occur is extensive, and has been reviewed in detail elsewhere (US PHS 1964; US DHEW 1979; US DHHS 1980, 1981, 1982, 1983, 1984; Selikoff and Lee 1978; Ontario, Royal Commission 1984; NRC 1984). However, populations with asbestos exposure commonly have coincident cigarette smoke exposure, and the magnitude of the risk of lung cancer and chronic lung injury produced by smoking necessitates a careful examination of the smoking habits of asbestos-exposed workers in order to define the risks of isolated and combined exposures.

A number of conditions or diseases known to be associated with smoking, asbestos, or both, including mesothelioma, heart disease, pleural plaques, adverse reproductive outcomes, and cancers other than lung, are not discussed here; the focus of this chapter is lung cancer and chronic lung disease, the disease processes for which the largest amount of data on the effects of combined exposure is available.

Asbestos-Exposed Populations

Some exposure to both cigarette smoke and asbestos appears to be an inescapable consequence of living in the urban U.S. environment. The relatively omnipresent nature of cigarette smoking as a social phenomenon makes at least incidental exposure to cigarette smoke a universal experience, and the digestion of lung tissue from individuals with no known asbestos exposure commonly reveals low concentrations of asbestos bodies and asbestos fibers (Churg and Warnock 1977, 1980). It is technically extremely difficult to establish the presence or absence of an effect in populations who have had no exposure to asbestos other than the levels in ambient air or who have not had repetitive exposure to smoke through active or involuntary smoking. However, it is generally accepted that these extremely low dose exposures do not substantially alter the occurrence of lung cancer or chronic lung disease in the general population (Ontario, Royal Commission 1984).

The same statement cannot be made for individuals with repetitive low dose or indirect exposures to either of these agents, however. Evidence continues to accumulate that shows that nonsmoker exposure to environmental tobacco smoke may carry with it an

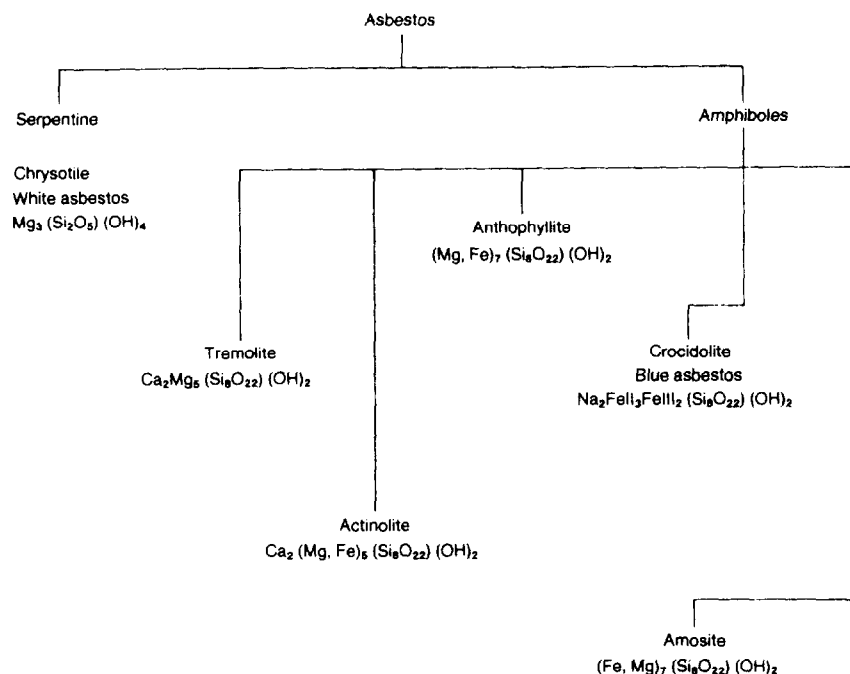


FIGURE 1.—Principal varieties of asbestos

SOURCE: Chatfield (1981).

increased risk of lung cancer (IARC, in press). The exposure of the wives and children of asbestos workers to asbestos on work clothing and in the home environment is thought to be associated with an increased risk for mesothelioma and possibly other diseases (Selikoff and Lee 1978). The risk from these low dose exposures is smaller than the risk for individuals directly exposed to these agents (active cigarette smokers and workers occupationally exposed to asbestos dust).

"Asbestos" refers to a specific group of fibrous silicates, the principle varieties of which are listed in Figure 1. Commercial use of asbestos stems from its qualities of resistance to heat and acid and its ability to be woven into fabric (Zoltai and Wylie 1979). Commercial products known as asbestos differ in the configurations and dimensions of their fibers as well as in their chemical makeup and crystalline structure. These properties determine, in part, the deposition patterns of fibers in the respiratory tract and the mechanisms whereby the fibers interact with the cells of the lung.